NATURAL GAS DEHYDRATION USING SILICA GEL: FABRICATION OF DEHYDRATION UNIT

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I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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I would like to dedicated this thesis to all those who believe in the richness of learning. Especially my beloved

Mother, Katisah Bt Husin

Father, Mohd Rohani Bin Johari

Siblings, and

Iskandar Izany Bin A Rahman

who have been great sources of motivation and inspiration.

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ABSTRACT

The purpose of this study is to remove water content in untreated natural gas using solid desiccant dehydration unit. Dehydration of natural gas is needed to remove the water that is associated with natural gases in vapor form. The natural gas industry has recognized that dehydration is necessary to ensure smooth operation of gas transmission lines. Dehydration prevents the formation of gas hydrates and reduces corrosion. Unless gases are dehydrated, liquid water may condense in pipelines and accumulate at low points along the line and reducing its flow capacity. Several methods have been developed to dehydrate gases on an industrial scale. The three major methods of dehydration are direct cooling, adsorption, and absorption. In this experiment, the adsorption process was choosing. Silica gel was the desiccants used in adsorption processes. The desiccant dehydration is a very simple process, ideal for remote locations with limited utilities, environment benefit, easy to install and operate and it also suitable in laboratory scale. In this study, it focuses on designing, fabrication, hydrostatic test and experimental part. On the experimental part, the quality of the desiccant and the temperature is constant because it only focuses on operating pressure. At a constant temperature the water content of the gas decreases with increasing pressure, thus less water must be removed if the gas is dehydrated at a high pressure.

ABSTRAK

Kajian ini dilakukan bertujuan untuk menyingkirkan kandungan air didalam gas asli mentah. Penyahhidratan pada gas asli adalah perlu untuk menyingkirkan air yang berada pada fasa wap. Industri gas asli telah mengakui bahawa penyahhidratan adalah perlu untuk melancarkan operasi pada aliran penghantaran. Pengecualian pada gas asli yang telah terhidrat, air mungkin termeluap pada aliran paip dan terkumpul pada takat terendah sepanjang aliran dan mengurangkan kapasiti aliran gas. Beberapa kaedah telah dihasilkan untuk menghidratkan gas pada skala industi. Tiga kaedah major untuk menghidratkan gas ialah penyejukan secara terus, penyerapan dan resapan. Di dalam eksperimen ini, proses resapan telah dipilih. Silika gel adalah bahan pengering yang digunakan dalam proses resapan. Unit penghidrat ini disebut unit penghidrat bahan pengering, proses ini merupakan proses yang mudah, sesuai untuk tempat terpencil yang mempunyai kurang kemudahan , pemasangan dan operasi yang mudah dan juga terdapat pada skala makmal. Di dalam kajian ini ia menfokuskan pada merekabentuk, membina, ujian cecair dan bahagian eksperimentasi. Pada bahagian eksperimentasi, kualiti bahan kering dan suhu adalah tetap kerana eksperimen ini hanya memfokuskan pada tekanan operasi. Pada suhu yang tetap, wap air berkurangan pada tekanan yang tinggi. Oleh itu, kandungan wap air adalah kurang terhidrat pada tekanan operasi yang tinggi.

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D	Diameter
L	Length
m	mass
M	Water content adsorbed
wt %	Weight Percentage
cm	centimetre
min	minutes
g	gram
m	meter

LIST OF ABBREVIATION

NG	Natural Gas
CH_4	Methane
C_2H_6	Ethane
C_3H_8	Propane
C_4H_{10}	Butane
CO_2	Carbon Dioxide
N_2	Nitrogen
He	Helium
H_2S	Hydrogen Sulfide

CHAPTER 1

INTRODUCTION

1.1 General

Natural gas is generally considered a nonrenewable gaseous fossil fuel. Most scientists believe that natural gas was formed from the remains of tiny sea animals and plants that died 200-400 million years ago. When these tiny sea animals and plants died, they sank to the bottom of the oceans where they were buried by layers of sediment that turned into rock. Over the years, the layers of sedimentary rock became thousands of feet thick, subjecting the energy-rich plant and animal remains to enormous pressure. Most scientists believe that the pressure, combined with the heat of the earth, changed this organic mixture into petroleum and natural gas. Eventually, concentrations of natural gas became trapped in the rock layers like wet sponge traps water. [1]

About 2,500 years ago, the Chinese recognized that natural gas could be put to work. The Chinese piped the gas from shallow wells and burned it under large pans to evaporate seawater for the salt. Natural gas was first used in America in 1816 to illuminate the streets of Baltimore with gas lamps. Lamplighters walked the streets at dusk to light the lamps. By 1900, natural gas had been discovered in 17 states. In the past 40 years, the use of natural gas has grown. Today, natural gas accounts for 21.6 percent of the energy we use. [1]

Raw natural gas comes primarily from any one of three types of wells that are crude oil wells, gas wells, and condensate wells. Natural gas that comes from crude oil wells is typically termed associated gas. This gas can exist separate from the crude oil in the underground formation, or dissolved in the crude oil. Natural gas from gas wells and from condensate wells, in which there is little or no crude oil, is termed non-associated gas. Gas wells typically produce only raw natural gas, while condensate wells produce raw natural gas along with a very low density liquid hydrocarbon called natural gas condensate (natural gasoline). [2]

The former Soviet Union holds the world's largest natural gas reserves, 38% of the world's total. Together with the Middle East, which holds 35% of total reserves, they account for 73% of world natural gas reserves. World's ratio of proven natural gas reserves to production at current levels is between 60 and 70 years. This represents the time that remaining reserves would last if the present levels of production were maintained. [3]

Total world production in 2000 was 2422.3 billion cubic meters. Production growth in 2000 was 4.3%, a significantly higher growth that the 1990-2000 annual average. World natural gas production is expected to grow in the future as a result of new exploration and expansion projects, in anticipation of growing future demand. [3]

Natural gas prices, as with other commodity prices, are driven by supply and demand fundamentals. Prices paid by consumers were increased from 1930 through 2205 by processing and distribution costs. U.S. natural gas prices were relatively stable at around (2006 US) $30/Mcm in both the 1930s and the 1960s. Prices reached a low of around (2006 US) $17/Mcm in the late 1940s, when more than 20 percent of the natural gas being withdrawn from U.S. reserves was vented or flared. [4]

Natural gas contains many contaminants, of which the most common undesirable impurity is water. It is necessary to eliminate water to avoid some problem to happen and to meet a water dew point requirement. Several methods can be used to dry natural gas and in this study, a solid desiccant dehydrator using silica gel is considered due to its ability to provide extremely low dew points. Solid desiccant dehydrator unit is very simple process and use adsorption process.

The rational of this research is to remove water vapor from natural gas that can reduce the potential for corrosion, hydrate formation, and freezing in the pipeline. It also stops sluggish flow conditions that may be caused by condensation of water vapor in natural gas.[5] Besides that, it produces what is known as 'pipeline quality' dry natural gas. Otherwise, there are no volatile organic compounds or aromatic hydrocarbon emissions by using solid desiccant dehydrator unit as a method to remove water vapor. [6]

1.2 Problem Statement

All natural gas well streams commonly exists in mixtures with other hydrocarbons, principally ethane, propane, butane, and pentanes. In addition, raw natural gas contains water vapor, hydrogen sulfide (H_2S), carbon dioxide, helium, nitrogen, and other compounds. As the gas travels up the well bore to the surface, it cools due to pressure reduction and heat conduction to cooler formations. The ability of gas to hold water vapor decreases as the gas temperature decreases, so natural gas is nearly always saturated with water vapor when it reaches the surface.

It is necessary to remove most of the water vapor for gas processing and transportation. Free water in a natural gas stream can result in line plugging due to hydrate formation, reduction of line capacity due to collection of free water in the line, and increased risk of damage to the pipeline due to the corrosive effects of water. Reducing the water vapor content of natural gas reduces its saturation temperature (or dew point), thereby reducing the chance that free water will form in the pipeline. [7]

The removal of the water vapor that exists in solution in natural gas requires a complex treatment. This treatment consists of dehydrating the natural gas, which usually involves one of two processes, either absorption, or adsorption. Absorption occurs when the water vapor is taken out by a dehydrating agent. Adsorption occurs when the water vapor is condensed and collected on the surface. In this research, the focus is on solid-desiccant dehydrator unit using silica gel.

1.3 Objective

The objectives of this research is

1) To remove water vapor from untreated natural gas by using solid (silica gel) desiccant dehydrator unit.

1.4 Scope of Study

1) Fabrication of a dehydration unit
    - The main component of the dehydration unit is clear PVC pipe with diameter 4 inches.
2) Experimental
    - The experiment will be carried out using four different pressures. The pressure range is from 0.1 to 0.4 bar. The relationship between the pressure and the water collected is considered in this present study.
3) Analyzing
    - The estimation of water collection will be done by differentiate the mass before and after of the silica gel. (Quantitative Analyzing)

CHAPTER 2

LITERATURE REVIEW

2.1 Natural Gas

2.1.1 Component of Natural Gas

Natural gas (NG) is a gaseous fossil fuel composed mainly by 70–90 mol% methane (CH_4), the remainder being higher molecular weight hydrocarbons, such as ethane (C_2H_6), propane (C_3H_8), and butane (C_4H_{10}). Water vapor, carbon dioxide (CO_2), nitrogen (N_2), helium (He), hydrogen sulfide (H_2S) can also be present. The exact composition of natural gas varies between gas fields. Natural gas that contains hydrocarbons other than methane is called wet natural gas. Natural gas consisting only of methane is called dry natural gas.

Table 2.1: Component of natural gas

Component	**wt. %**
Methane (CH_4)	70-90
Ethane (C_2H_6)	5-15
Propane (C_3H_8) and Butane (C_4H_{10})	< 5
Water vapor,CO_2, N_2, H_2S, etc.	balance

(http://www.naturalgasbank.com)

2.1.2 Natural Gas Use

Natural gas is a bridge to a sustainable energy system in the future and there is a need to put research on the alternatives such as hydrogen and biofuel. [8] As a clean alternative, it produces relatively few pollutants, so the air inside and outside stays clean. Natural gas ranks number three in energy consumption, after petroleum which provides almost 39 % of energy demand and coal which provide 22.6%. Natural Gas also has fewer emissions than coal or oil and has virtually no ash particles left after combustion. [1]

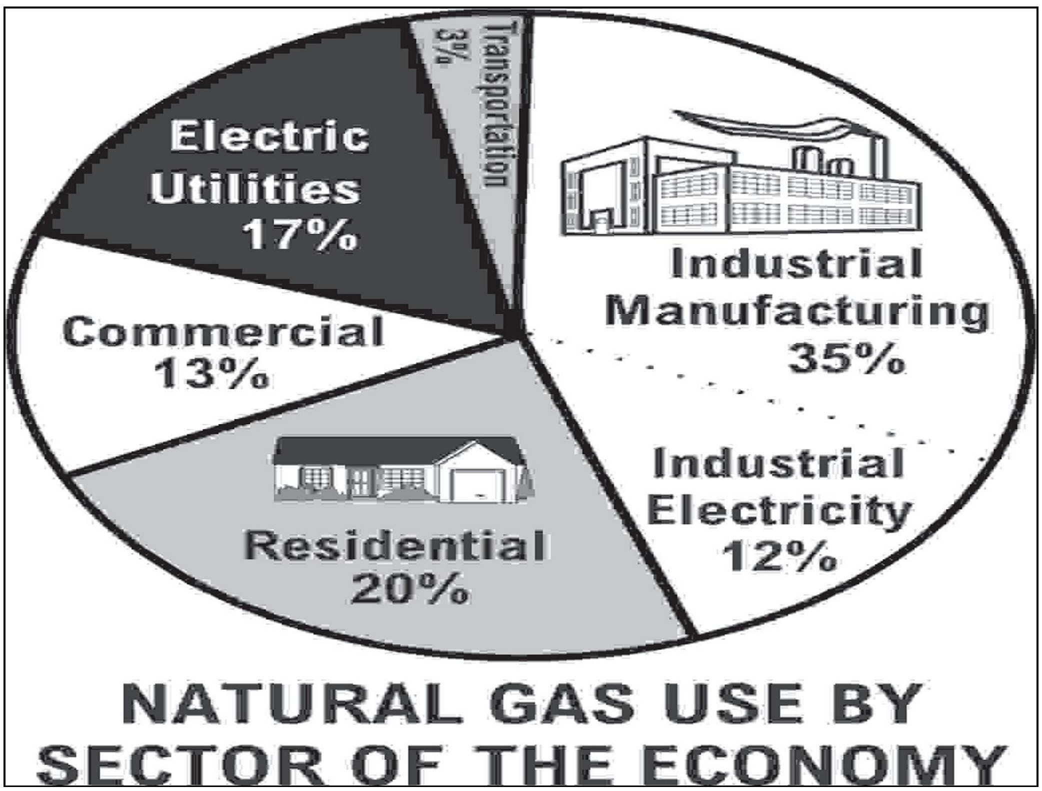

Figure 2.1: Natural gas use by sector of the economy

Industrial manufacturing is the biggest consumer of natural gas, 35 %, using it mainly as a heat to manufacture goods. Industry also uses natural gas as an ingredient in fertilizer, photographic film, ink, glue, paint, plastic, laundry detergent and insect repellents. Synthetic rubber and man-made fiber like nylon also could not be made without the chemicals derived from natural gas.

The residential and commercial sectors are the second biggest uses of natural gas, 20%. Natural gas is supplied to homes, where it is used for such purposes as cooking in natural gas-powered ranges and ovens, natural gas-heated clothes dryers, heating/cooling and central heating. Commercial use of natural gas is mostly for indoors heating of stores, office buildings, schools and hospitals. Natural gas is a major source of electricity generation through the use of gas turbines and steam turbines. Compressed natural gas (methane) is a cleaner alternative to other automobile fuels such as gasoline and diesel. Natural gas is a major feedstock for the production of ammonia, via the Haber process, for use in fertilizer production. Natural gas can be used to produce hydrogen, with one common method being the hydrogen reformer. [9]

2.1.3 Natural Gas processing

Natural gas processing begins at the wellhead (Figure 2.2). The composition of the raw natural gas extracted from producing wells depends on the type, depth, and location of the underground deposit and the geology of the area. The processing of wellhead natural gas into pipeline-quality dry natural gas can be quite complex and usually involves several processes. Various types of processing plants have been utilized since the mid-1850 s to extract liquids, such as natural gasoline, from produced crude oil. However, for many years, natural gas was not a sought after fuel. Prior to the early 20thcentury, most of it was flared or simply vented into the atmosphere, primarily because the available pipeline technology permitted only very short-distance transmission.

Figure 2.2 shows a schematic block flow diagram of a typical natural gas processing plant. It shows the various unit processes used to convert raw natural gas into sales gas pipelined to the end user markets. The block flow diagrams also shows how processing of the raw natural gas yields byproduct sulfur, byproduct ethane, natural gas liquids (NGL) propane, butanes and natural gasoline.

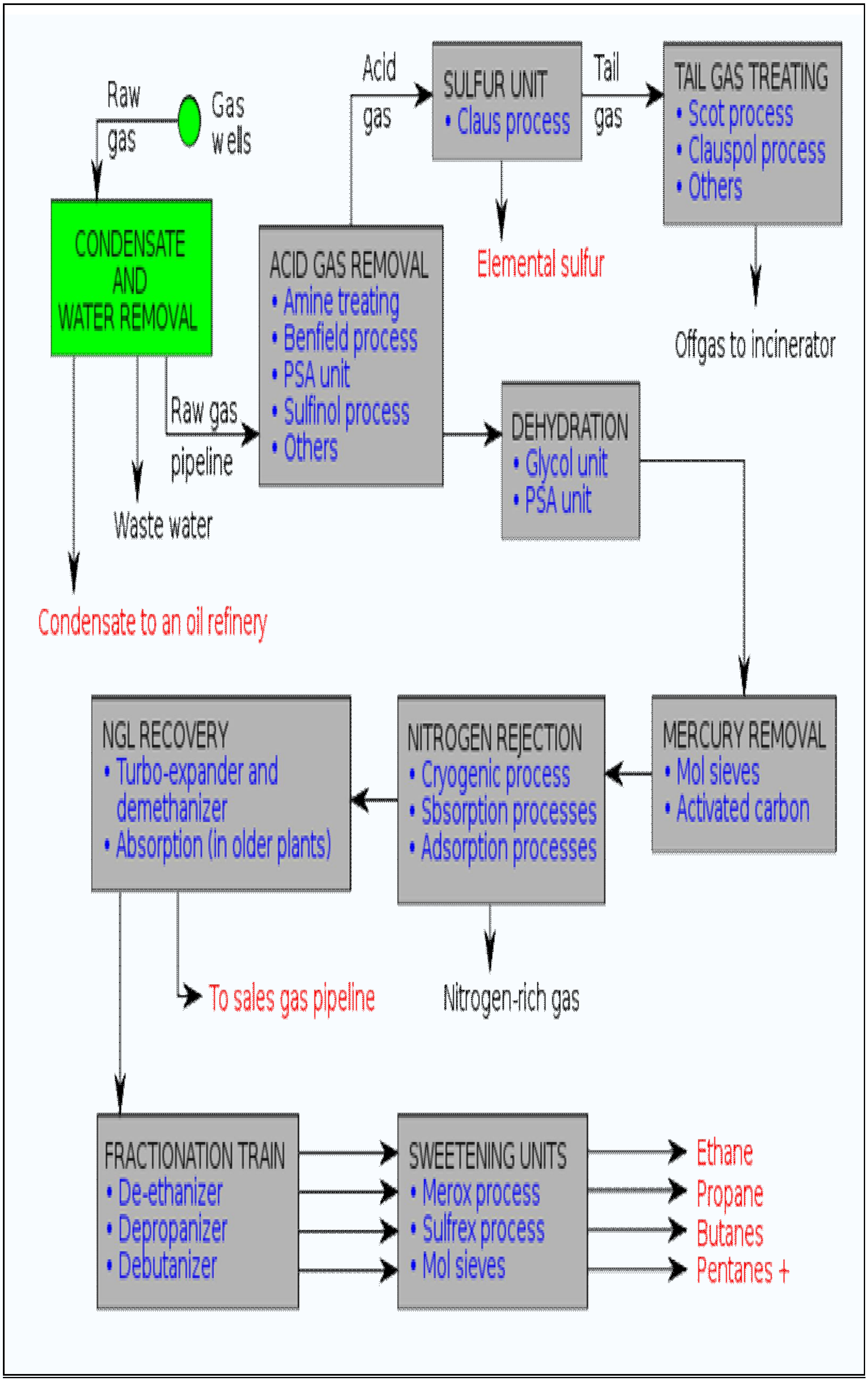

Figure 2.2: Natural gas processing
(http://en.wikipedia.org/wiki/Natural_gas_processing)

Natural gas, as it is used by consumers, is much different from the natural gas that is brought from underground up to the wellhead. Although the processing of natural gas is in many respects less complicated than the processing and refining of crude oil, but it is necessary before its use by end users. All natural gas well streams contain many contaminants, of which the most common undesirable impurity is water. So that, free water associated with extracted natural gas is removed by simple separation methods at or near the wellhead. Removal of water from the gas stream reduces the potential for corrosion, hydrate formation, and freezing in the pipeline. It is necessary to remove water vapor from natural gas and in this study the method use is using solid desiccant dehydrator unit using silica gel.

2.2 Gas Dehydration

Natural gases either from natural production or storage reservoirs contain water, which condense and form solid gas hydrates to block pipeline flow and especially control systems. Natural gas in transit to market should be dehydrated to a controlled water content to avoid hydrate as well as to minimize the corrosion problems.

Natural gas processing consists of separating all of the various hydrocarbons and fluids from the pure natural gas. Major transportation pipelines usually impose restrictions on the make-up of the natural gas that is allowed into the pipeline. That means that before the natural gas can be transported it must be purified. While the ethane, propane, butane, and pentanes must be removed from natural gas, this does not mean that they are all 'waste products'.

The natural gas received and transported by the major intrastate and interstate mainline transmission systems must meet the quality standards specified by pipeline companies in the “General Terms and Conditions (GTC)” section of their tariffs. These quality standards vary from pipeline to pipeline and are usually a function of a pipeline system’s design, its downstream interconnecting pipelines, and its customer base. In general, these standards specify that the natural gas: [9]

i. be within a specific Btu content range (1,035 Btu per cubic feet, +/- 50 Btu)

ii. be delivered at a specified hydrocarbon dew point temperature level (below which any vaporized gas liquid in the mix will tend to condense at pipeline pressure)

iii. contain no more than trace amounts of elements such as hydrogen sulfide, carbon dioxide, nitrogen, water vapor, and oxygen

iv. be free of particulate solids and liquid water that could be detrimental to the pipeline or its ancillary operating equipment.

Dehydration of natural gas is the removal of the water that is associated with natural gases in vapor form. The natural gas industry has recognized that dehydration is necessary to ensure smooth operation of gas transmission lines. Dehydration prevents the formation of gas hydrates and reduces corrosion. Unless gases are dehydrated, liquid water may condense in pipelines and accumulate at low points along the line, reducing its flow capacity. Several methods have been developed to dehydrate gases on an industrial scale.

The three major methods of dehydration are direct cooling, adsorption, and absorption. Molecular sieves (zeolites), silica gel, and bauxite are the desiccants used in adsorption processes. In absorption processes, the most frequently used desiccants are diethylene and triethylene glycols. Usually, the absorption/stripping cycle is used for removing large amounts of water, and adsorption is used for cryogenic systems to reach low moisture contents. [10]

2.2.1 Direct Cooling

The saturated vapor content of natural gas decreases with increased pressure or decreased temperature. Thus, hot gases saturated with water may be partially dehydrated by direct cooling. Gases subjected to compression are normally after cooled, and this cooling may well remove water from the gas. The cooling process must reduce the temperature to the lowest value that the gas will encounter at the prevailing pressure to prevent further condensation of water. [10]

2.2.2 Absorption of Water in Glycols

Absorption dehydration involves the use of a liquid desiccant to remove water vapor from the gas. Although many liquids possess the ability to absorb water from gas, the liquid that is most desirable to use for commercial dehydration purposes should possess the following properties:

i. high absorption efficiency.
ii. easy and economic regeneration.
iii. non-corrosive and non-toxic.
iv. no operational problems when used in high concentrations.
v. no interaction with the hydrocarbon portion of the gas, and no contamination by acid gases. [10]

The glycols, particularly ethylene glycol (EG), diethylene glycol (DEG), triethylene glycol (TEG), and tetraethylene glycol (T4EG) come to closest to satisfying these criteria to varying degrees. Water and the glycols show complete mutual solubility in the liquid phase due to hydrogen-oxygen bonds, and their water vapor pressures are very low. One frequently used glycol for dehydration is triethylene glycol, or TEG. This is mainly an absorption/stripping type process, similar to the oil absorption process. The wet gas is dehydrated in the absorber, and the stripping column regenerates the water-free TEG. The glycol stream should be recharged constantly because some TEG may react and form heavy molecules, which should be removed by the filter.